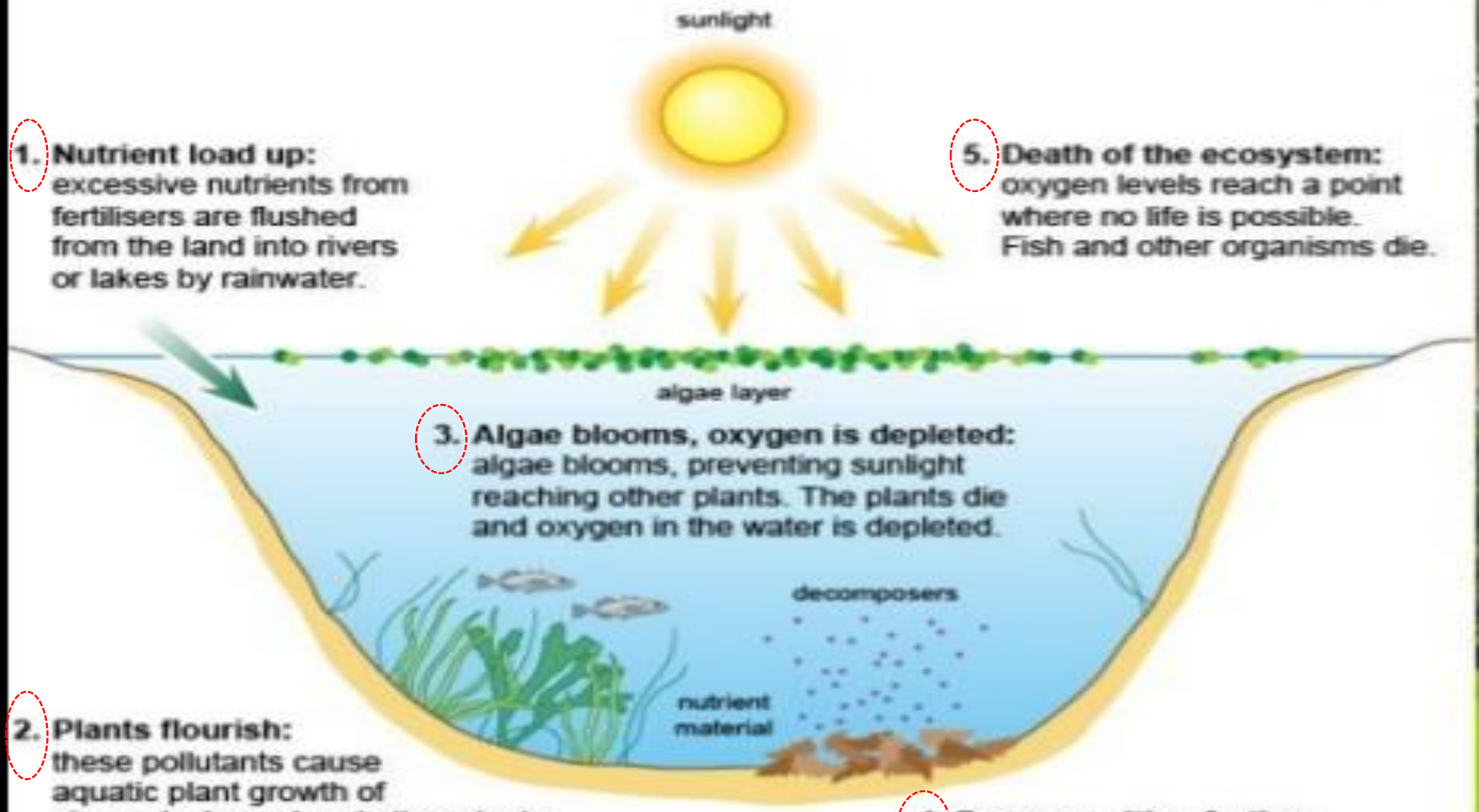
PREPARING For The ALGAE BLOOMS

WHAT GOT US HERE & CONCERNS

Time



1. **Nutrient load up:** excessive nutrients from fertilisers are flushed from the land into rivers or lakes by rainwater.

2. **Plants flourish:** these pollutants cause aquatic plant growth of algae, duckweed and other plants.

3. **Algae blooms, oxygen is depleted:** algae blooms, preventing sunlight reaching other plants. The plants die and oxygen in the water is depleted.

4. **Decomposition further depletes oxygen:** dead plants are broken down by bacteria decomposers), using up even more oxygen in the water.

5. **Death of the ecosystem:** oxygen levels reach a point where no life is possible. Fish and other organisms die.

One of the Most Important Lakes in the World ???

- Dead lake image of 60s and 70s.
- Poster child for pollution problems in this country.
- But, most heavily utilized of any of the Great Lakes.
- Shared by 4 states and 2 countries.
- Best example of ecosystem recovery in world.

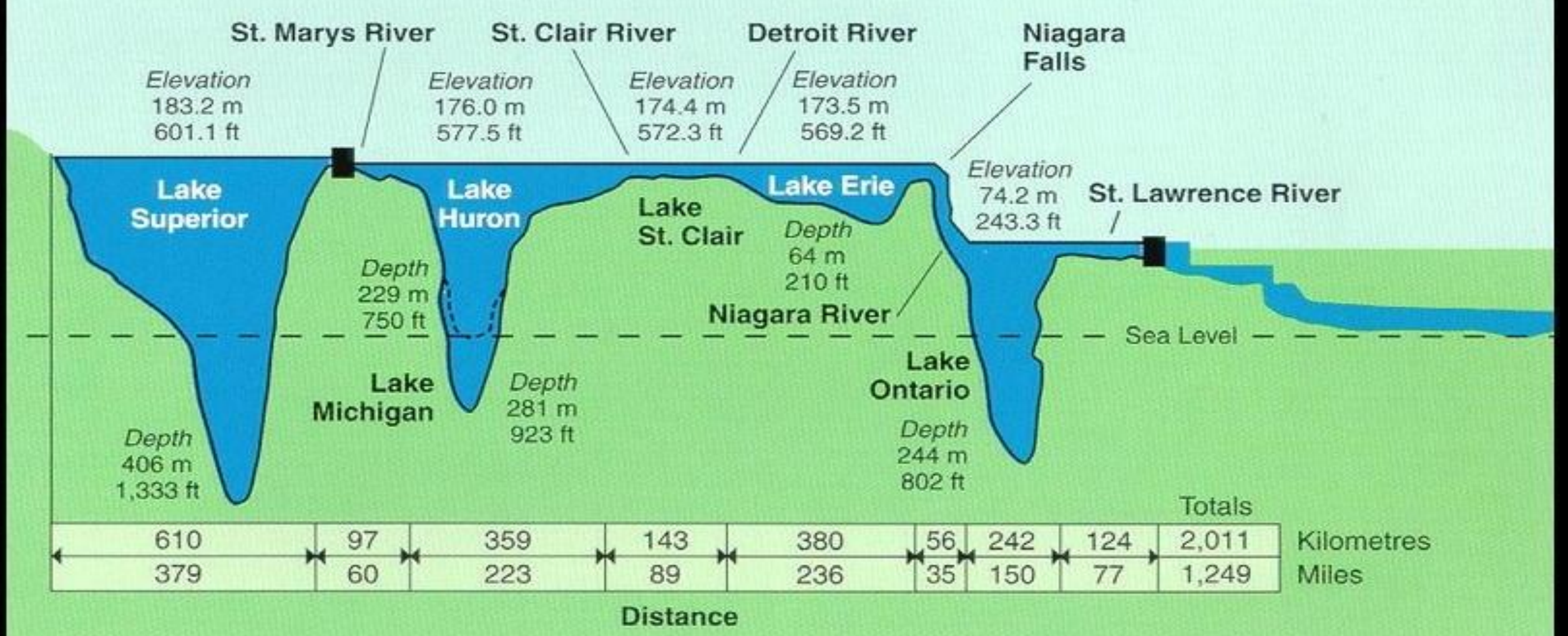
WHO AM I ???

One of the Most Important Lakes in the World ???

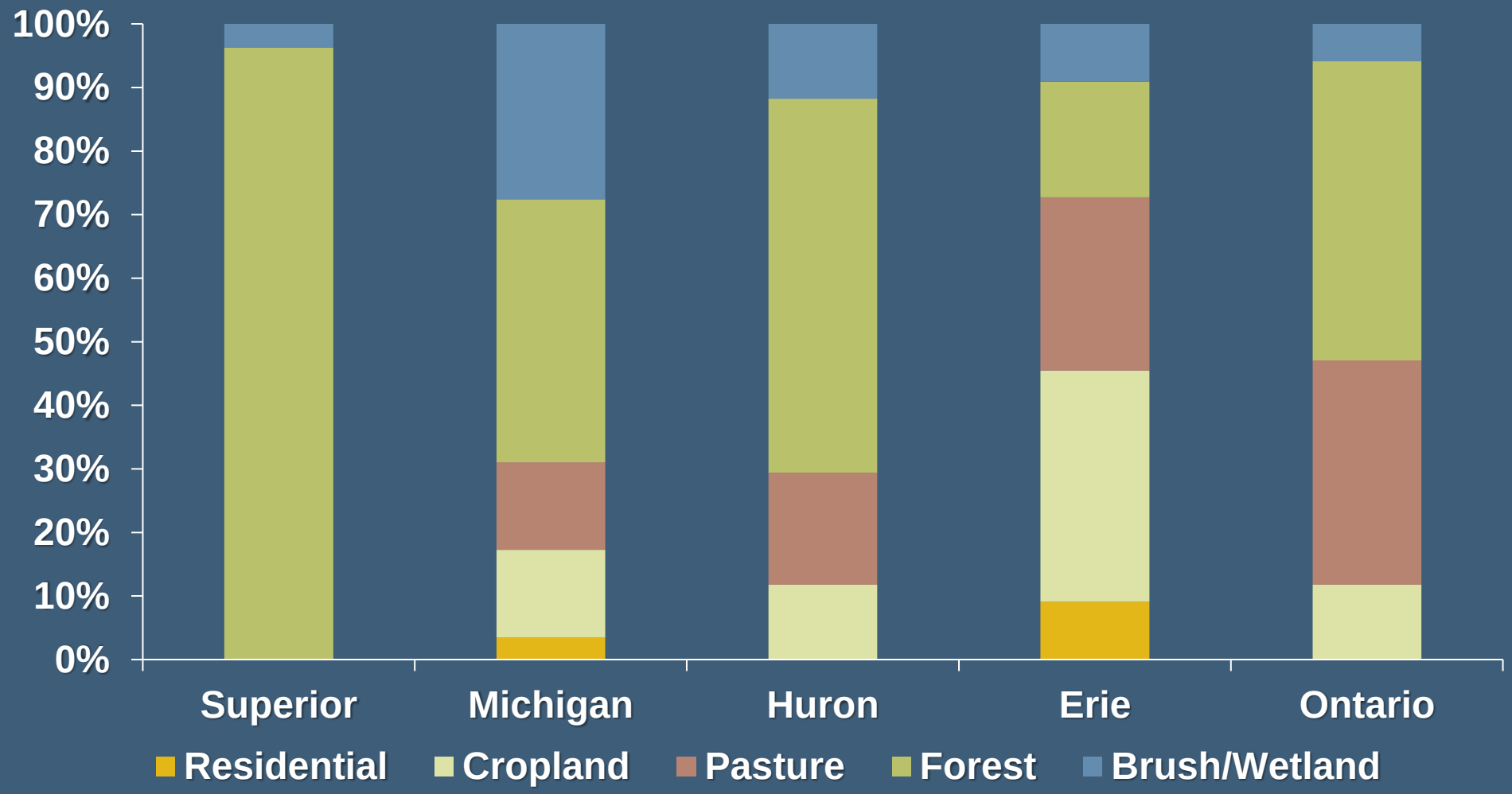
- **Name the four States:**

- **New York**, **Pennsylvania**, **Ohio**, and **Michigan**

Great Lakes Profile



Major Land Uses in The Great Lakes

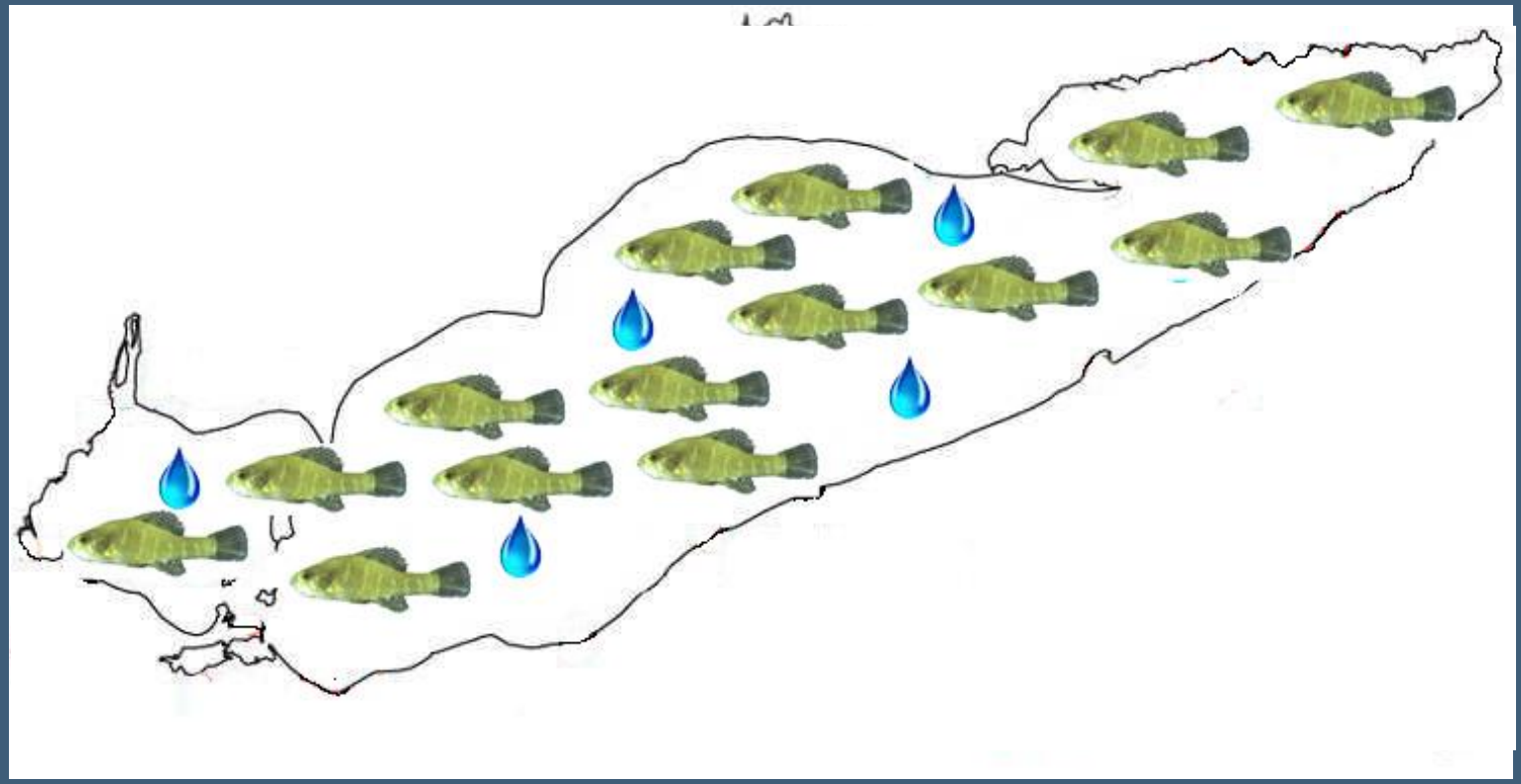


Because of Land Use, Lake Erie Gets:

- More sediment
- More nutrients (fertilizers and sewage)
- More pesticides
- And Lake Erie is still biologically the most productive of the Great Lakes—And always will be!!

50:2 Rule

(Not exact, but instructive)



Lake Superior:

20% of the water and 50% of the fish

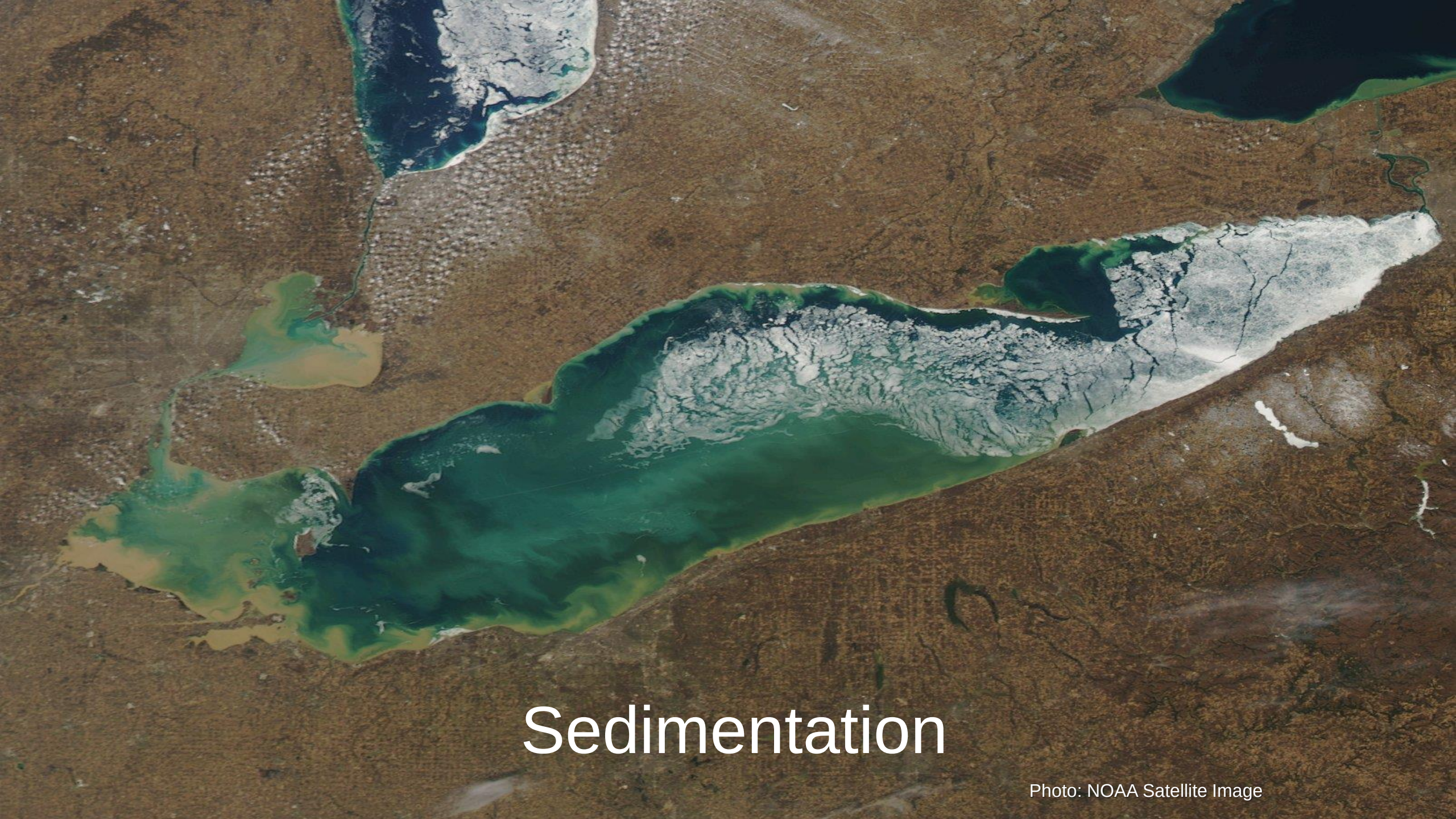

LAKE ERIE
CHARTER BOAT ASSOC
LIMIT OUT
MARBLEHEAD, OH

Lake Erie Stats

- Drinking water for 11 million people
- Over 20 power plants
- Power production is greatest water use
- 300 marinas in Ohio alone
- Walleye Capital of the World
- 40% of all Great Lakes charter boats
- Ohio’s charter boat industry is largest in North America
- $1.5 billion sport fishery
- One of top 10 sport fishing locations in the world
- The most valuable freshwater commercial fishery in the world
- Coastal county tourism value is over $10 billion

Lake Erie's Biggest Problems/Issues

- Sedimentation
- Phosphorus and nutrient loading
- Harmful algal blooms
- Aquatic invasive species
- Dead Zone
- Coastal Economic Development



Sedimentation

Photo: NOAA Satellite Image

Stone Lab
September 11, 2011

OXYGEN DEPLETION

Photo: Jeff Reutter


OXYGEN REQUIREMENTS
mg/L
14
13
12
11
10
9
8
7
6
5
4
3
2
1
TROUT
7
SALMON
6
BLUEGILL
5
BASS
5
CARP
5
PERCH
5
MUSKIE
4
WALLEYE
5
PIKE
2
BACTERIA
1

Why does Lake Erie get most nutrients?

- The most agriculture in its basin
- Few forests
- Wetlands gone
- Large human population — septic tanks, sewage treatment (or lack thereof)

MAUMEE RIVER BASIN

- At 8,316 square miles, the Maumee is the largest river basin in all the Great Lakes.

Why are we targeting phosphorus?

- Normally limiting nutrient in freshwater systems
- P reduction is best strategy ecologically and economically
- Reducing both P and N would help

How to Determine your Nutrient Load

Nutrient Ratio needed to complete Biochemical Oxygen Demand by Microorganisms

100 : 5 : 1

Carbon : Nitrogen : Phosphorous

180 mg/L CBOD / 100 = 1.8

25 mg/L NH_3-N / 1.8 = 13.9

5 mg/L Phosphorous-P / 1.8 = 2.8

Are we sure phosphorus reductions will solve the problem?

Phosphorus Sources

- 1960s and 70s—primarily point sources (2/3)
- Today loading is coming primarily from agriculture (2/3) but other sources include:
  - Sewage treatment plants and CSOs
  - Lawn fertilizer runoff
  - Water treatment plants ?????????
  - Septic tanks

Impacts of Increased Phosphorus Concentrations


IE COLONIAL
EST. 1905
NIESE FAMILY - OWNERS & OPERATORS
May 27, 1988

BLUE GREEN Algae Facts

- The optimum pH for most algae species is 8.2 to 8.7. Neutral or lower water pH, decreases the growth of algae.
- **Low temperatures slow algae growth, which blooms and multiplies in warm temperatures of approximately 60 to 81 degrees Fahrenheit.**
- *During the DAY, a*lgae draws carbon dioxide from the water to utilize during photosynthesis, promoting cell growth.
- Removal of carbon dioxide from the water raises the pH levels, as a result of the reduction in carbonate and bicarbonate levels of water, since they are used to replenish the lost carbon dioxide. Depletion of inorganic carbon from water by algae results in high pH levels, as evidenced by the rise in pH levels of natural waters, which can go up to 10 or beyond in the presence of algae. The rise of water pH also causes ionization of ammonia which is detrimental to aquatic life. (NH_4 to NH_3)
- At night, no photosynthesis takes place, so algae stops taking in carbon dioxide from water and goes into a respiratory stage

During this respiratory stage, algae consumes oxygen that was produced during photosynthesis and releases carbon dioxide into the water.

HAB Requirements

- Warm water (summer problem but now finding them in Maumee River as early as April)
- High phosphorus levels
- Zebra/quagga mussels (not required but remove competition)

Microcystin Concentrations

- 1 ppb WHO drinking water limit
- 20 ppb WHO swimming limit
- 60 ppb highest level for Lake Erie until 2011
- 84 ppb highest level for Grand Lake St. Marys
- 2000+ Grand Lake St. Marys 2010
- 1200 Lake Erie Maumee Bay area 2011


2010 three dogs die in Grand Lake St. Mary’s from algae toxins

THE UNTHINKABLE HAPPENED

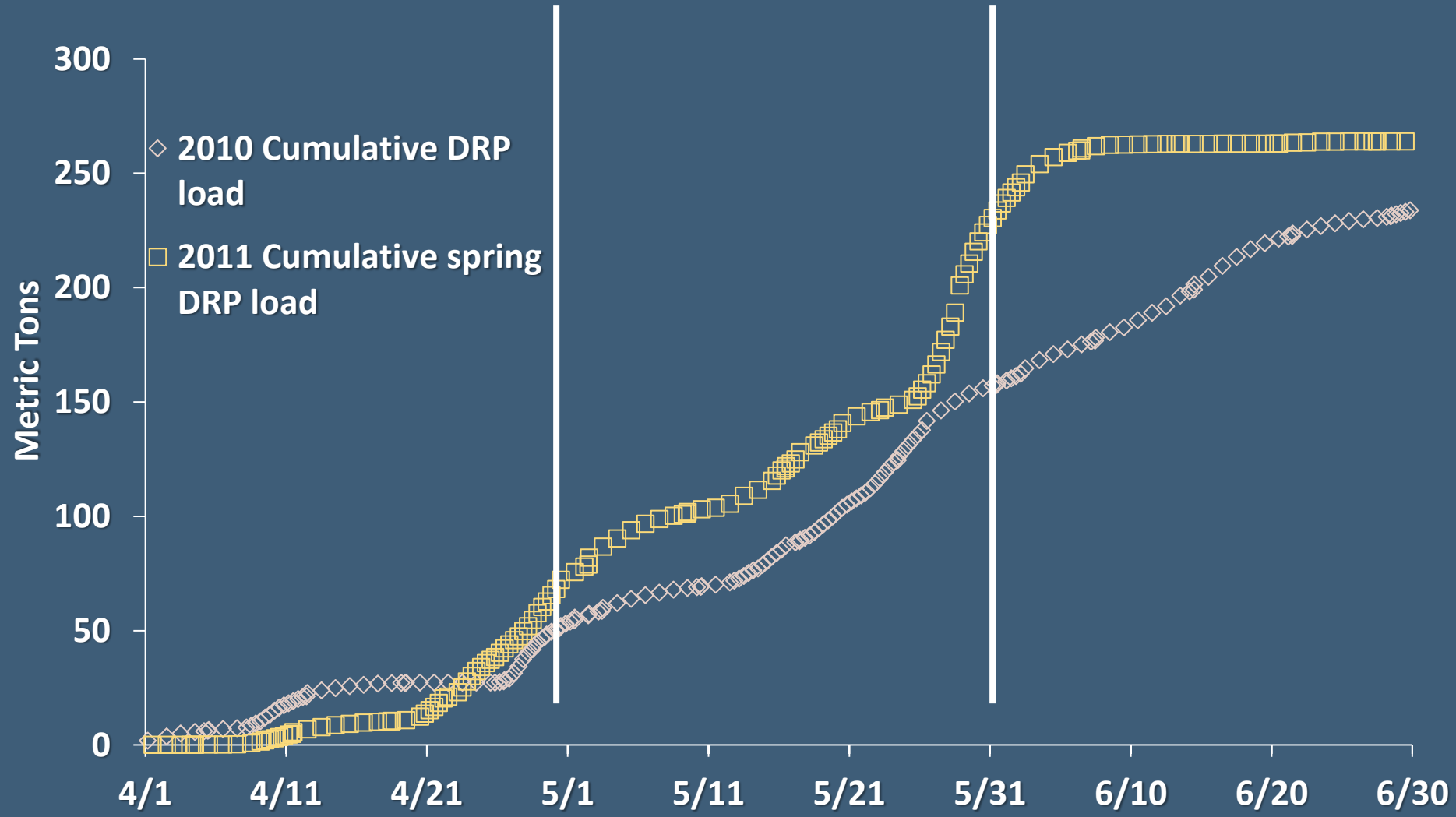
SATURDAY, AUG. 2, 2014

2 a.m. - The City of Toledo issues a "Do Not Drink" notice, warning residents to not drink the water, boil it or bathe in it because of an algae bloom in Lake Erie contaminating the city's water supply.

Target Load Reduction

- To solve the harmful algal bloom problem (HAB) and reduce the size and duration of the dead zone in the Central Basin of Lake Erie, the overall annual load of soluble reactive or dissolved phosphorus to Lake Erie should be reduced by 2/3.
- All sources should reduce by 2/3!!

Dissolved Reactive Phosphorus Spring Loads



Nutrient Loading

- Majority of loading occurs during storm events
- 90% of loading occurs 10% of time

October 9, 2011

Photo: NOAA Satellite Image

Microcystis near Marblehead

HABs:
Western Basin Problem but Contribute to Oxygen Demand in the Central Basin, i.e. the Dead Zone

Lake Erie Cross Section

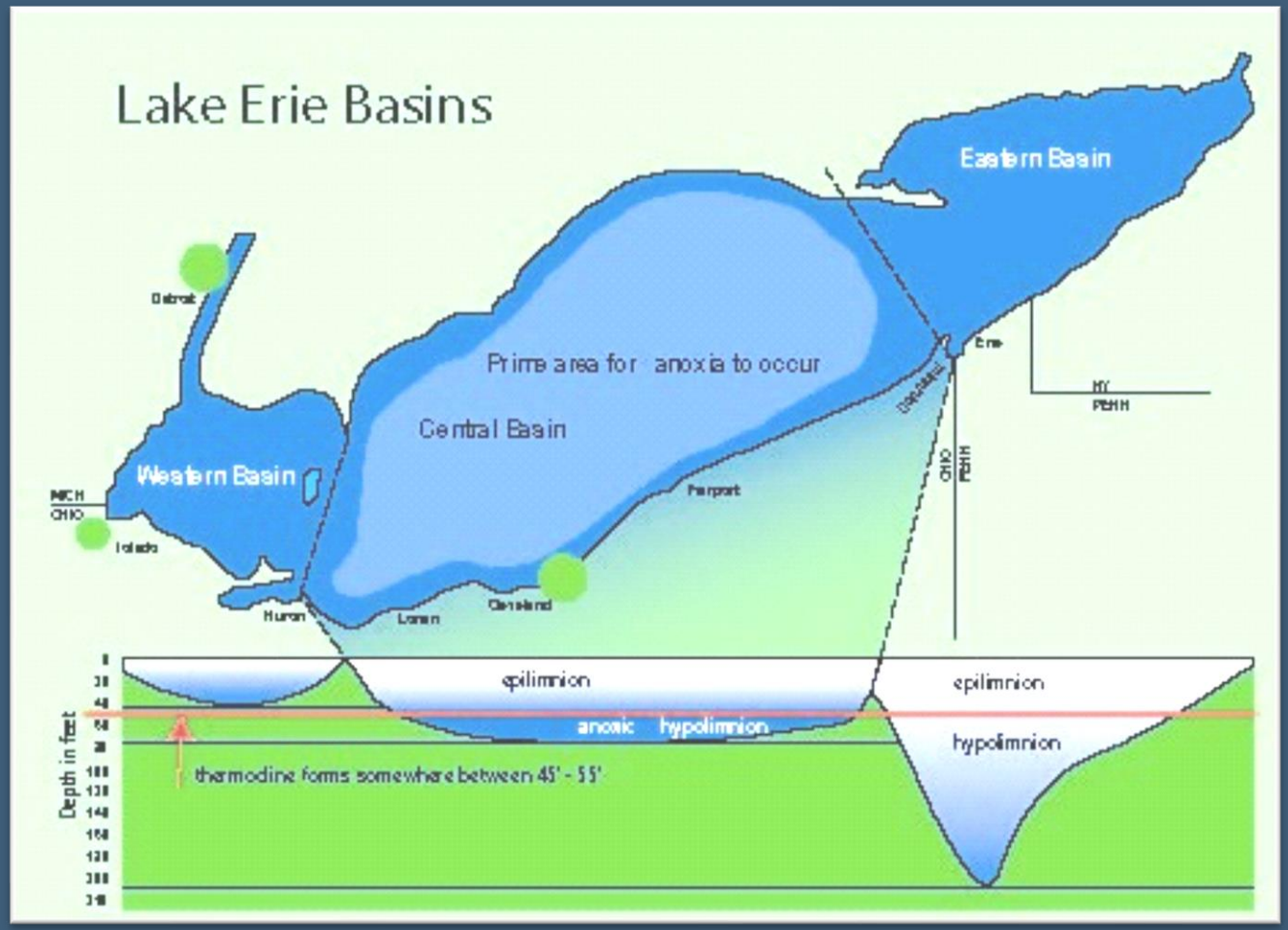
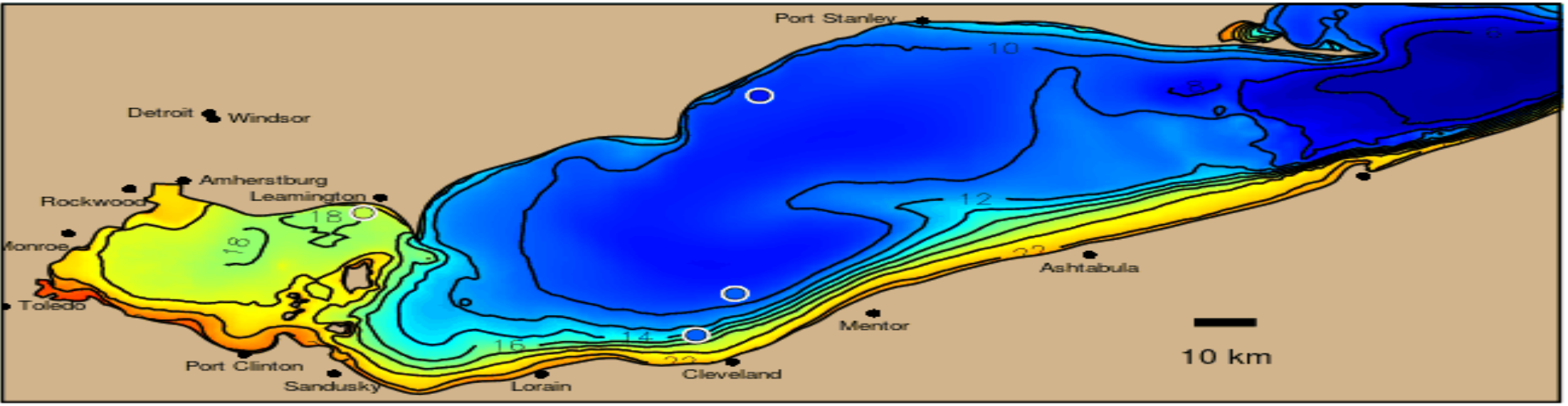
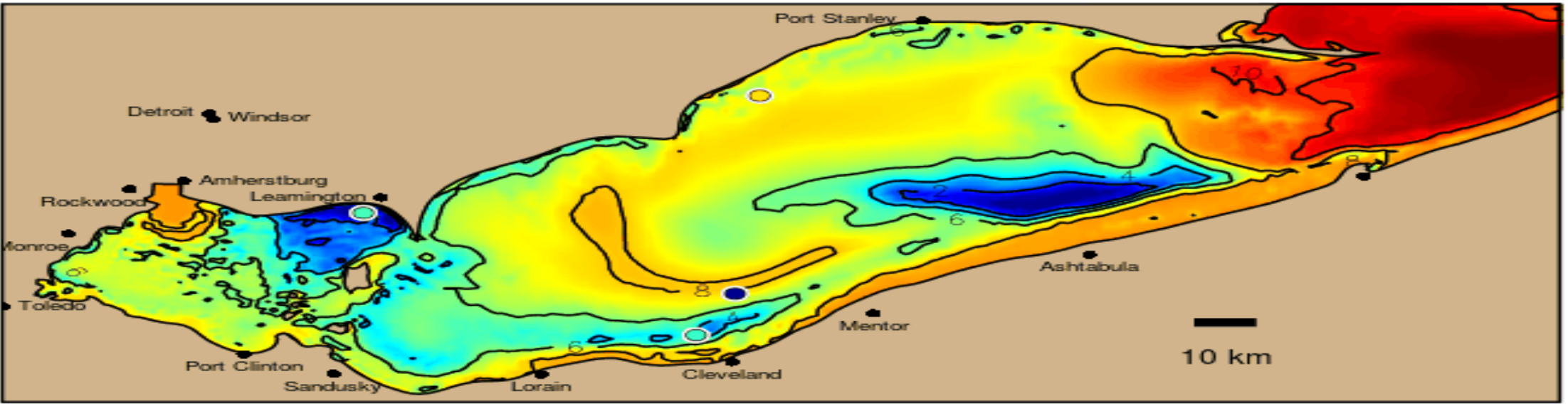


Image: Ohio Sea Grant

Sun 30 Jun 2019 01:00 EDT

2019-06-30 05 GMT





Possible Agriculture Action Areas

-
- Eliminate fall and winter application of fertilizer and manure.
- Eliminate broadcast application and incorporate the fertilizer into soil.
- Soil testing of all fields to determine if we are missing some real problem spots and to prevent application of too much.
- Do not apply P at levels above agronomic needs recommended by OSU.
- Use appropriate fertilizer, e.g., don’t apply nitrogen in fall/winter
- Do not apply fertilizer when rain is forecast to occur within 48 hours.
- Place a moratorium on the addition of more tiles to remove water from agricultural fields. It appears that over 50% of the dissolved phosphorus leaving fields is going through the tiles—POINT SOURCES
- Consider reducing the size of farms falling under CAFO regulations so more of the unregulated operations are regulated.
- Improve recommendations made by soil testing laboratories regarding amount of P to be added (30% of Ohio fields have too much P already)

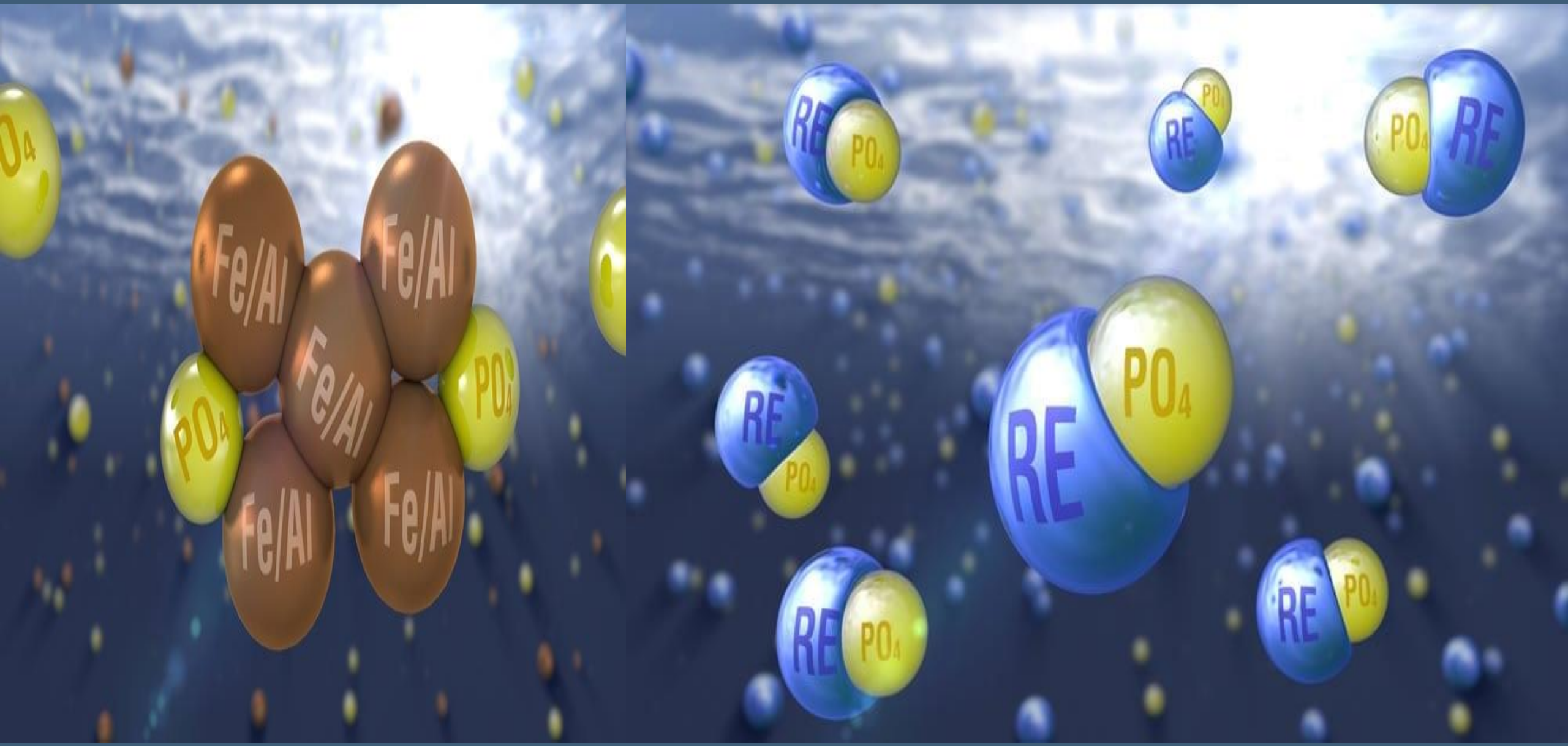
What other levers can we turn?

- **Lawn Care Recommendations**
- Encourage Scott's and all lawn care fertilizer sellers and their applicators to meet the zero P goal set by Scott’s.

- **Sewage Treatment Plant Recommendations**
- Cut allowable discharge levels of P in half.
- Expedite actions to eliminate CSOs.

- **Septic Tanks**
- Assure that all septic tanks are connected and working properly.

WWTP Investigating Rare Earth Minerals

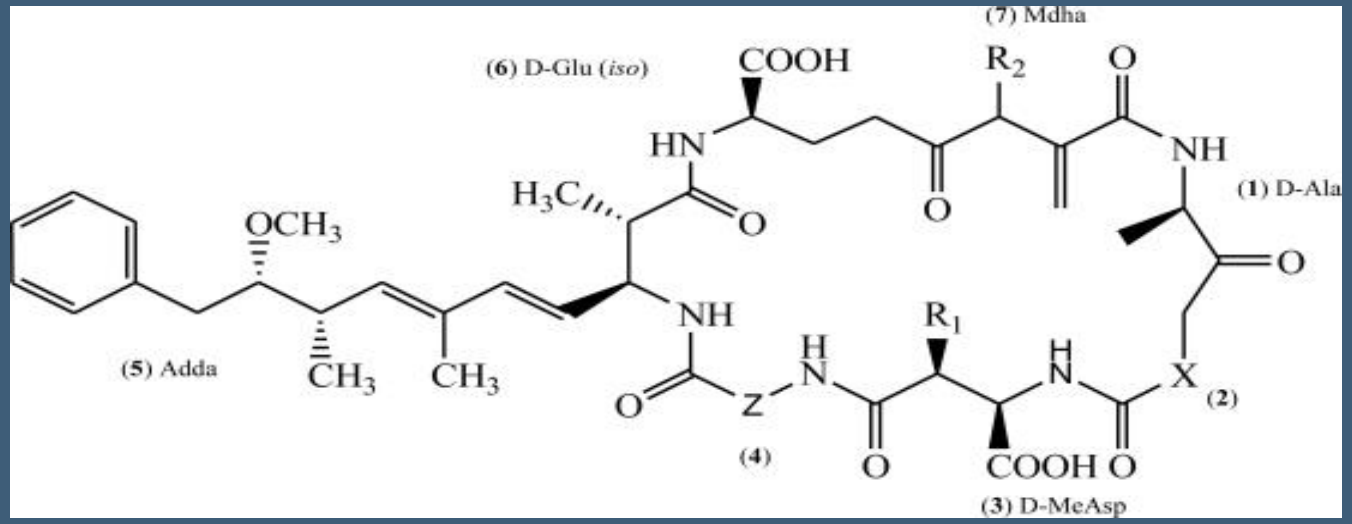



WWTP practicing BNR
EBPR
PHOSPHORUS UPTAKE
ANOXIC ZONE
Influent
Effluent
Inside Channel
Middle Channel
Outer Channel
1
2
3
4
5
6
7
8
9

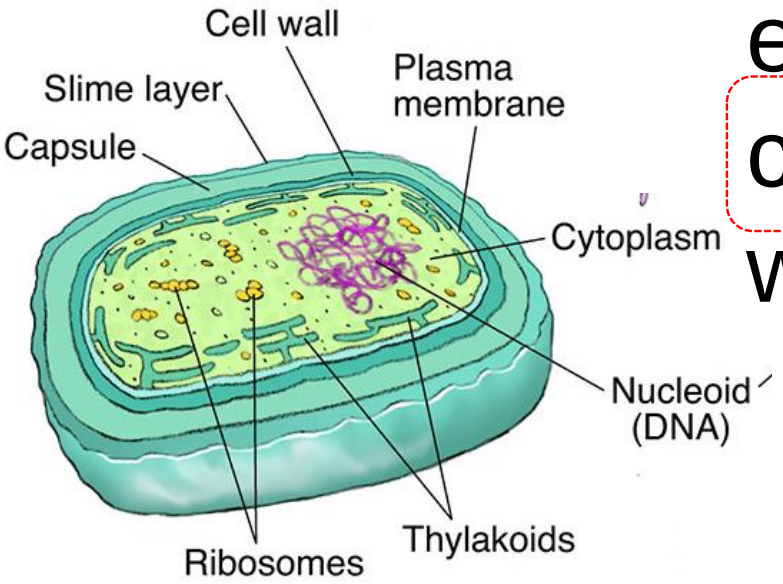
Expected Time for Recovery

- Because Lake Erie is the smallest of the Great Lakes by volume, the retention time for water in the Lake is very short compared to the other 4 lakes—Western Basin retention time is 20-50 days. Therefore, if reduced loading targets are reached, recovery will be almost immediate.

Beware of ME !



My Name is ***MICROCYSTIN*** ***Microcystins (MC) are potent hepatotoxins produced by the cyanobacteria of the genera Planktothrix, Microcystis, Aphanizomenon, Nostoc and Anabaena. These cyclic heptapeptides have strong affinity to serine/threonine protein phosphatases (PPs) thereby acting as an inhibitor of this group of enzymes.***

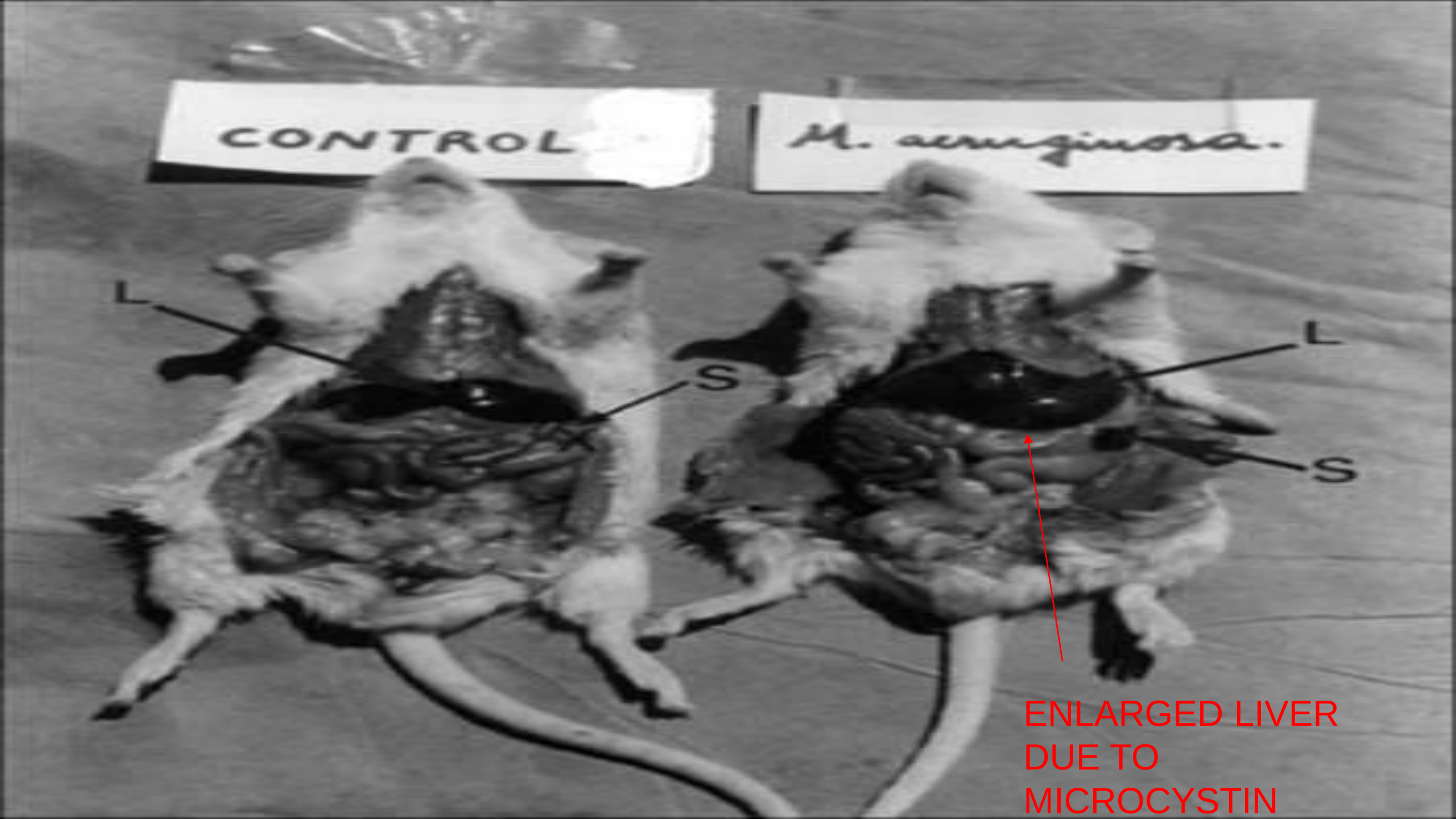


A. Photosynthetic bacterium (cyanobacteria)

In most cases, the cyanobacterial toxins naturally exist intracellularly (in the cytoplasm) and are retained within the cell.

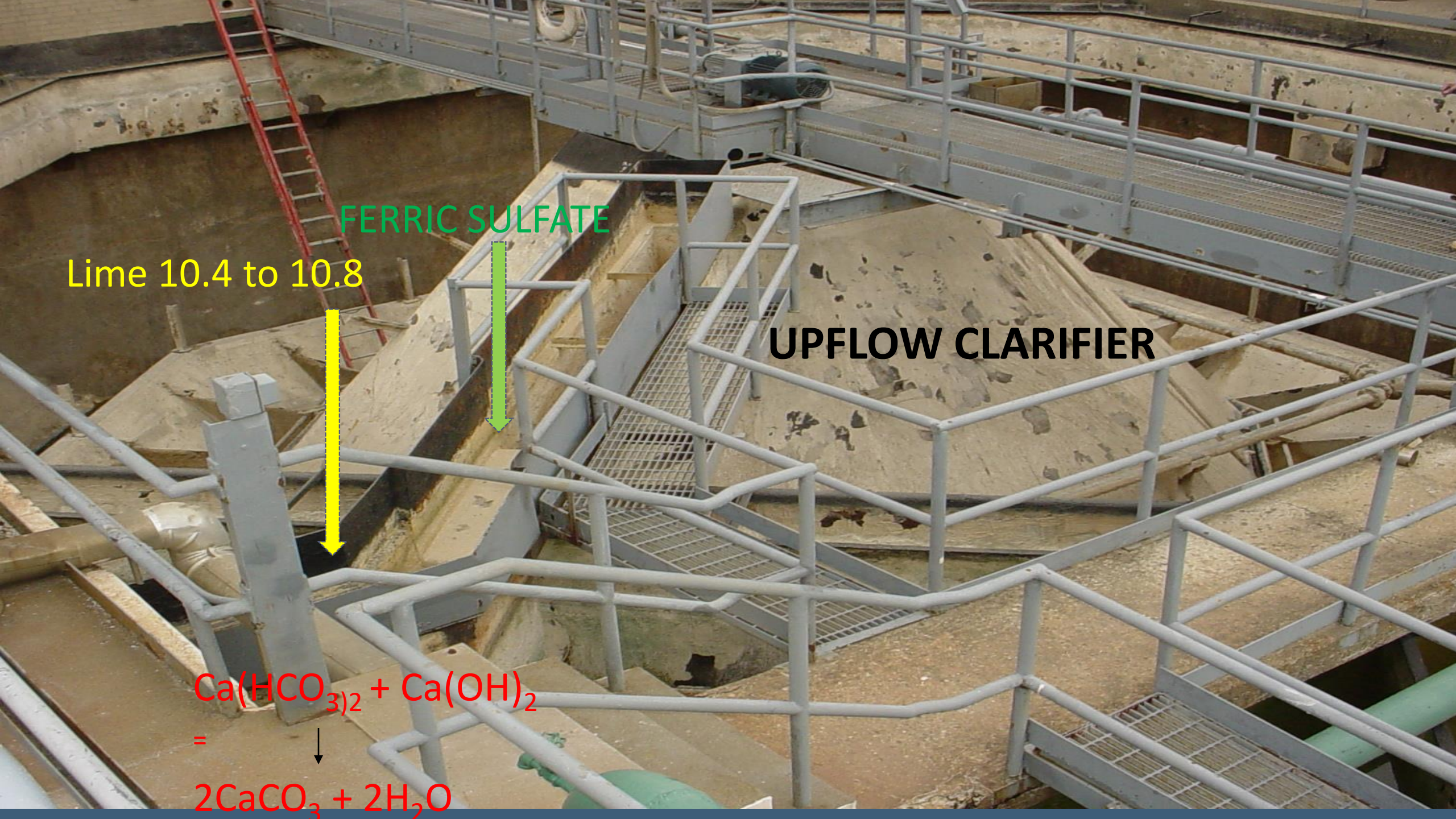
Table 1. Cyanotoxins on the Contaminant Candidate List (CCL)

Cyanotoxin	Number of known variants or analogues	Primary organ affected	Health Effects[1]	Most common Cyanobacteria producing toxin[2]
Microcystin-LR	80~90	Liver	Abdominal pain Vomiting and diarrhea Liver inflammation and hemorrhage Acute pneumonia Acute dermatitis Kidney damage Potential tumor growth promotion	*Microcystis* *Anabaena* *Planktothrix* *Anabaenopsis* *Aphanizomenon*
Cylindrospermopsin	3	Liver		*Cylindrospermopsis* *Aphanizomenon* *Anabaena* *Lyngbya* *Rhaphidiopsis* *Umezakia*
Anatoxin-a group[3]	2-6	Nervous System	Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death	*Anabaena* *Planktothrix* *Aphanizomenon* *Cylindrospermopsis* *Oscillatoria*

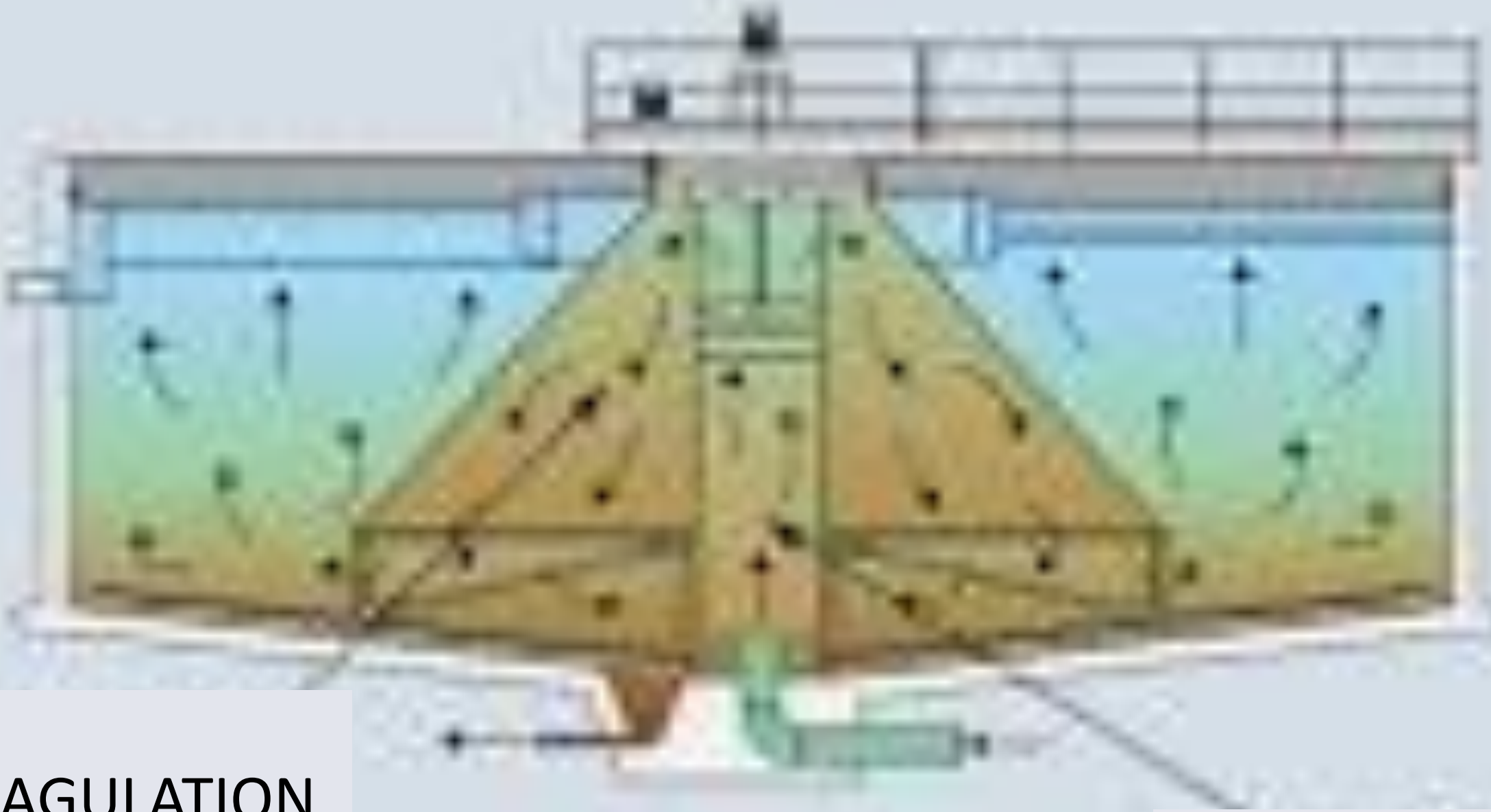

CONTROL
M. aeruginosa.
L
S
L
S
ENLARGED LIVER
DUE TO
MICROCYSTIN


Filtra

Conventional treatment using coagulation will remove cyanobacteria cells; however, sludge containing toxic cyanobacteria should be isolated from the treatment process as cells contained in sludge can break down rapidly and release dissolved toxin.


FERRIC SULFATE
Lime 10.4 to 10.8
UPFLOW CLARIFIER
$Ca(HCO_{3)2} + Ca(OH)_2$
=
$2CaCO_3 + 2H_2O$

HOW IT WORKS



COAGULATION ZONE

MIXING ZONE

COAGULATION DIAGRAM

Bacterial cell wall has a negative charge

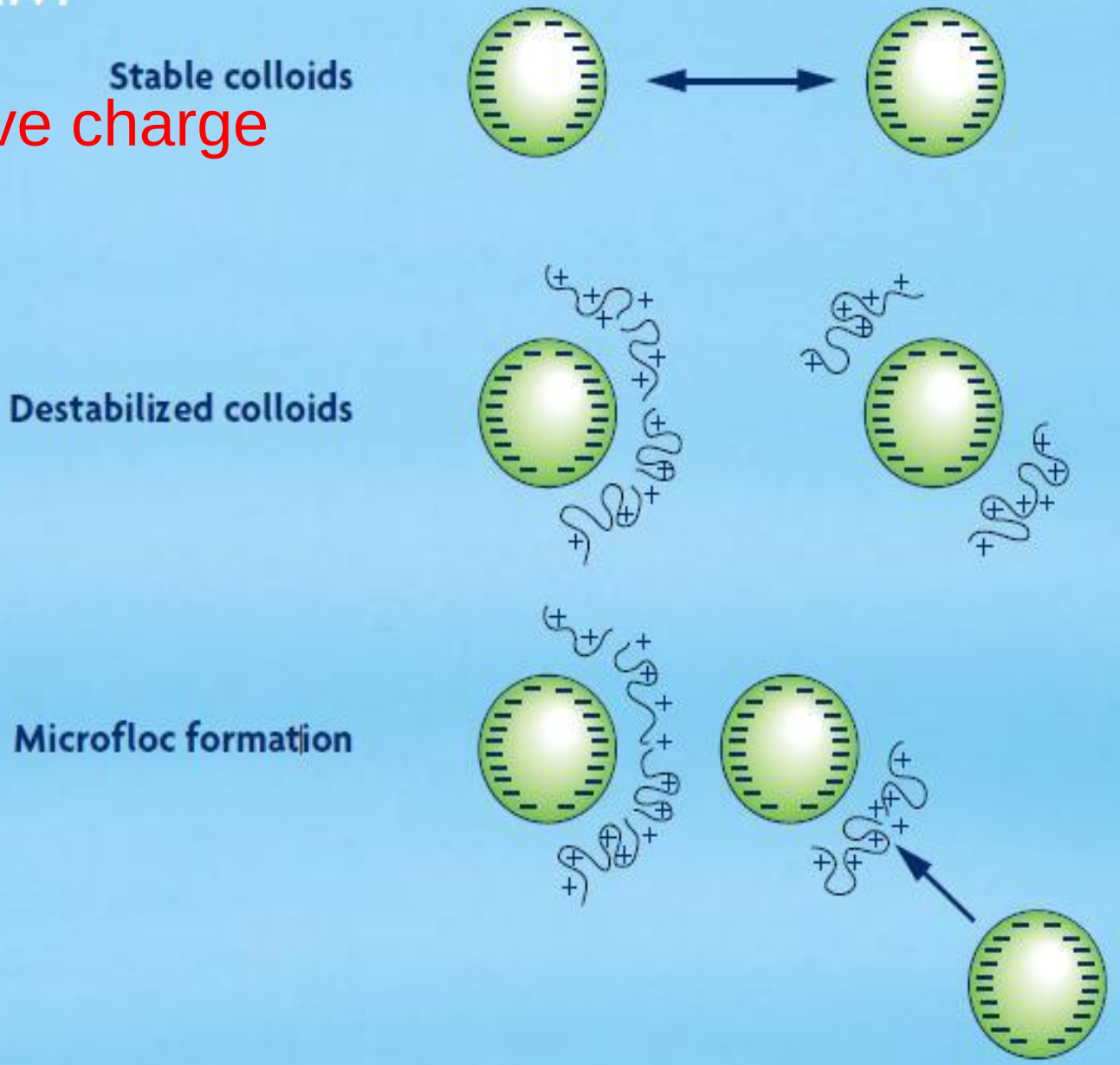
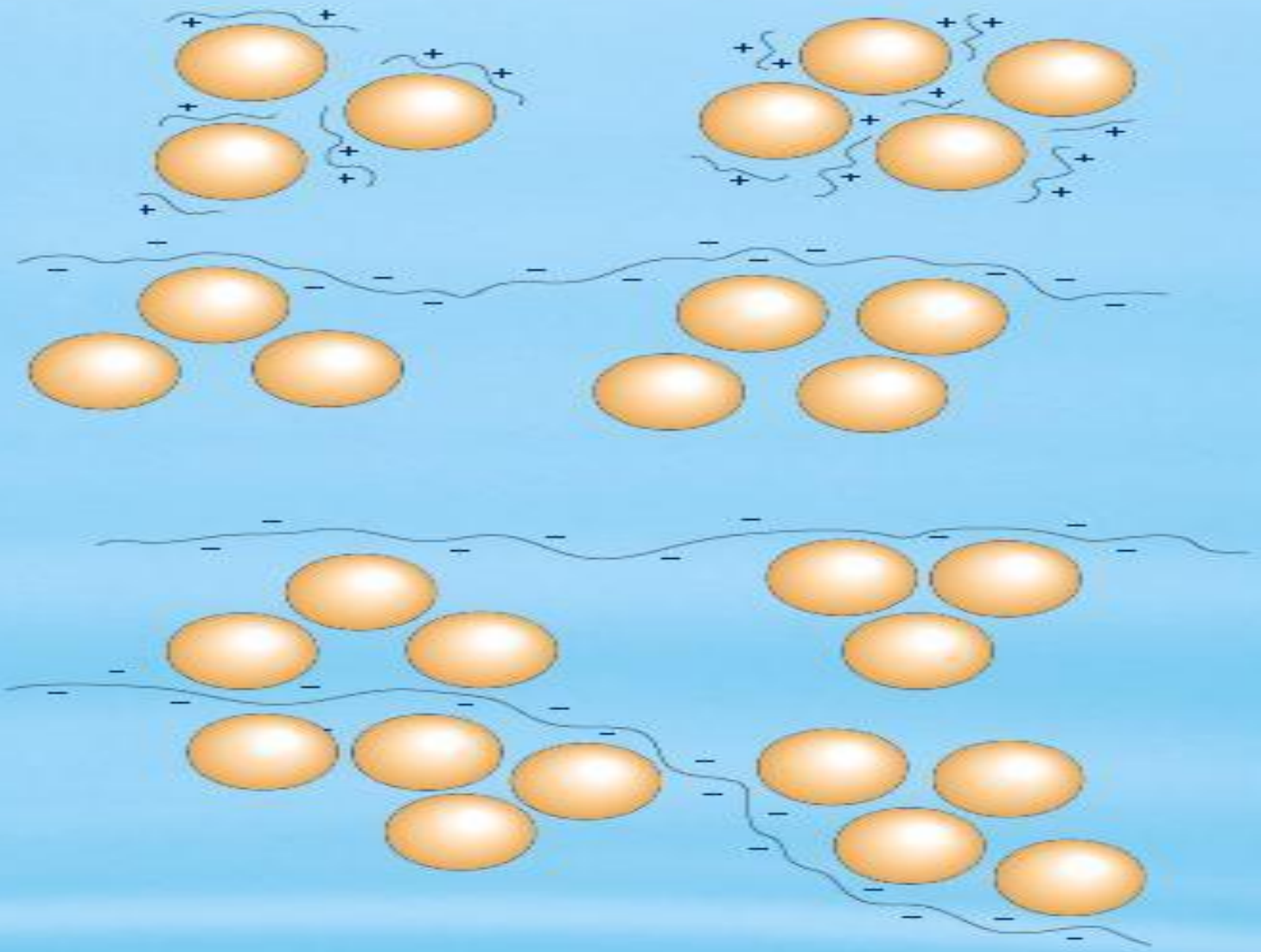


DIAGRAM OF FLOCCULATION



Floc Formation

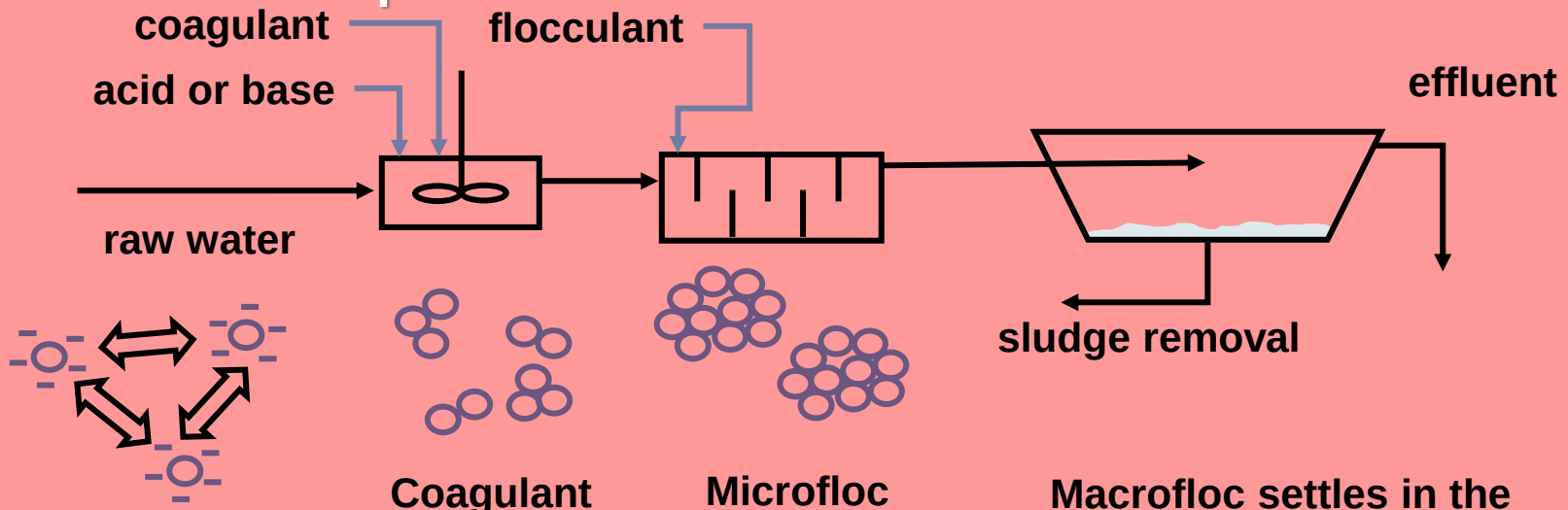
The goal of flocculation is to promote growth of flocs to a size that can be removed by sedimentation and filtration.

WHY IS THE NEED FOR EXCESS LIME?

Water utilities struggling with high source water calcium and/or magnesium often turn to lime softening to remove hardness. Raising treatment pH above 9.6 converts soluble calcium bicarbonate hardness to insoluble calcium carbonate, and further pH increases beyond 10.6 begin to convert soluble magnesium bicarbonate to insoluble magnesium hydroxide. Aggressive magnesium removal often requires a treatment pH of 11 or higher, a process known as excess lime softening. Precipitation of magnesium hydroxide produces water quality benefits.

Let's REVIEW: Coagulation, flocculation, and settling

- Removes suspended solids from raw water.



Surface charges cause particles to repel one another.

Coagulant neutralizes charge. Microfloc forms.

Microfloc continues to coalesce until large macrofloc appear.

Macrofloc settles in the sedimentation basin. Clear supernatant leaves the basin.

A very effective way to deal with high microcystin concentrations therefore is to remove the cells, intact and without damage (Drikas et al. 2001; Hart et al. 1998). Any damage, such as that caused by preoxidation, may lead to cell leakage, and consequently in an increase of the dissolved toxin concentration on entering the treatment plant. This may be critical, as dissolved toxin is not removed by conventional treatment technologies.

TOLEDO'S INTAKE

Chlorination and ozonation are effective for the removal of microcystins. A residual of at least 0.3 mg/ L of ozone for 5 minutes will be sufficient for all of the most common microcystins

For chlorine a dose of 3 mg/ L applied to obtain a residual of 0.5 mg/L for at least 30 minutes will be effective.

- Granular activated carbon filtration displays a limited lifetime for all toxins. This can vary between 2 months to more than one year depending on the type of toxin and water quality.

NOTE:

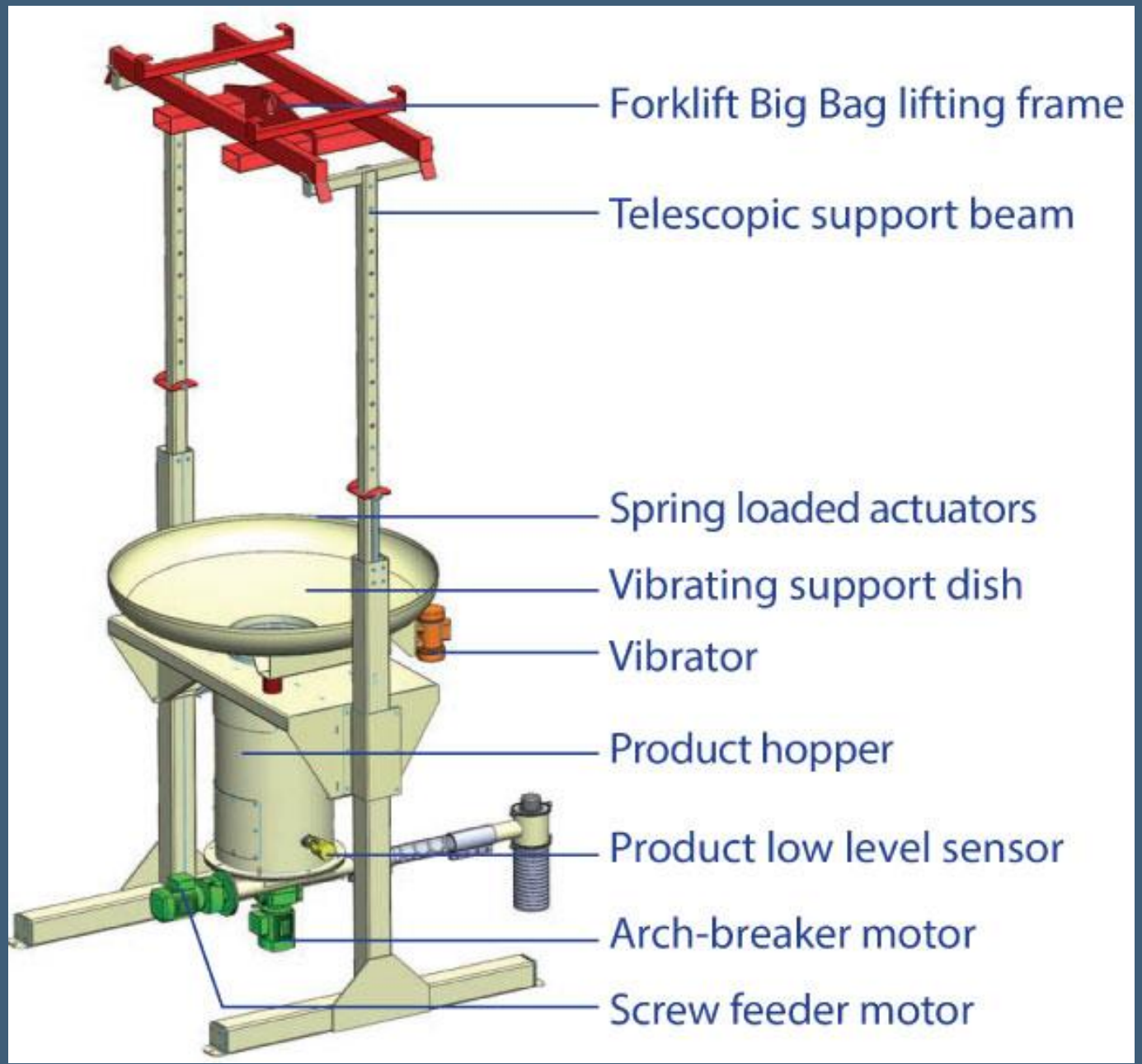
- Natural Organic Matter (NOM) breakthrough occurred prior to the MC-LR breakthrough and NOM preloading appears to affect the rate of MC-LR breakthrough. To determine your spent granular carbon capacity, doing Total Organic Carbon (TOC) testing will give you a better response time for granular carbon replacement and MC-LR breakthrough.

Removal of extracellular (free) cyanotoxins

Powdered activated carbon and granular activated carbon are very effective, depending on the carbon dose, the type of carbon (*wood-based powdered activated carbon for microcystin and cylindrospermopsin) and contact time (> 30 minutes recommended*); Coupling preoxidation with activated carbon is an effective way to remove both cyanotoxins and their potential transformation products. Moreover, the carbon must be regenerated or replaced at routine intervals, often based on the breakthrough of total organic carbon; however, toxin breakthrough may occur before significant total organic carbon breakthrough is detected.

Questions to ask yourself

- Have you checked out your equipment ?
- Do you have spare parts on hand?
- Is the Feed System delivering the right amount?
- Has the Chemical shelf life expired?



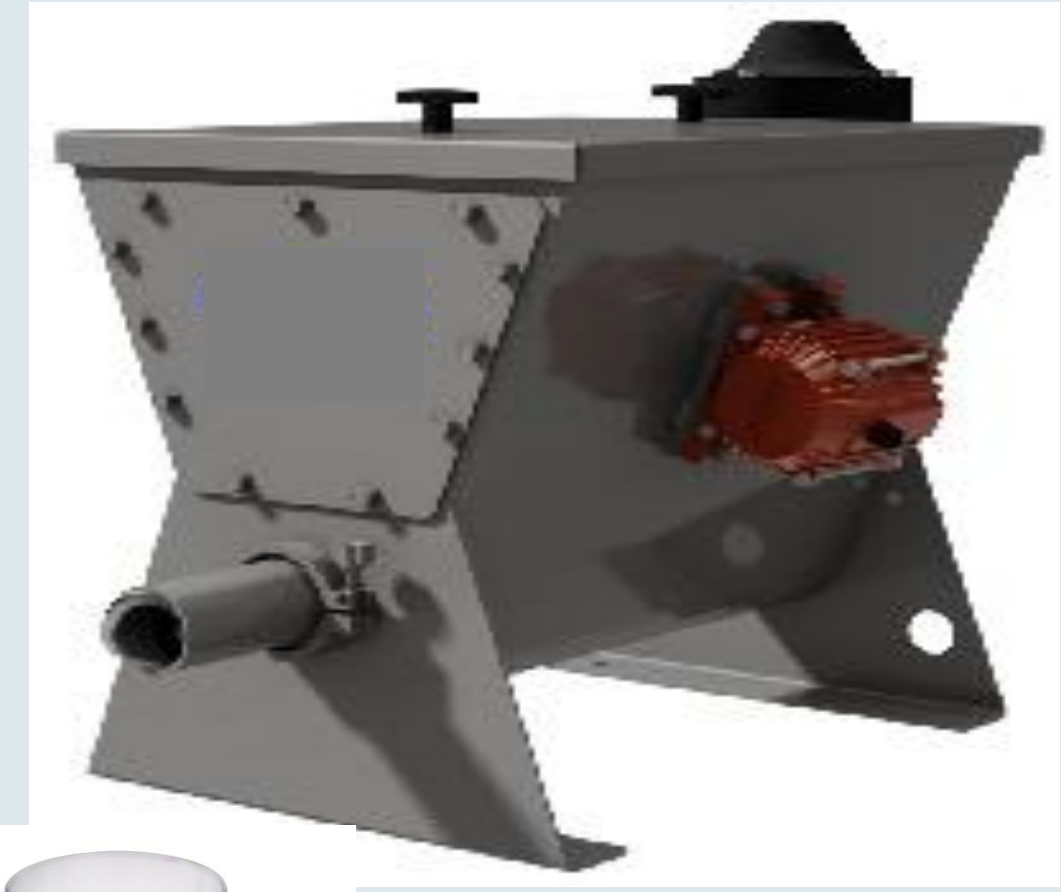
ADD PAC & Polymer after CO_2

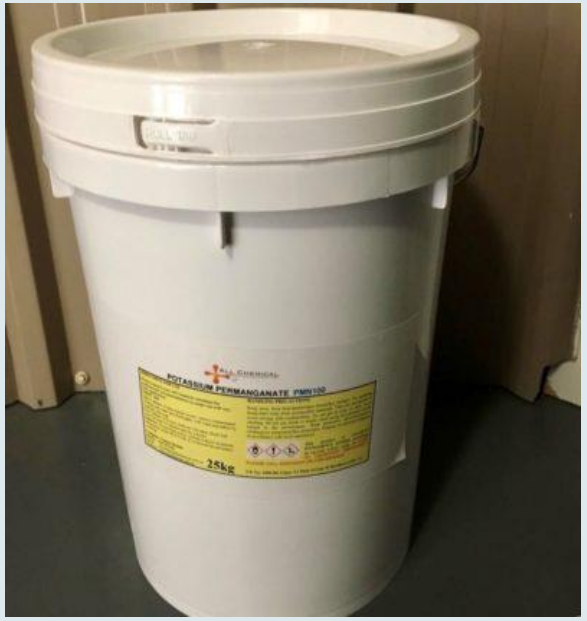
CO_2

High pH due to excess Lime

Microcystin LA may require a higher residual
, as it is slightly less susceptible to
oxidation by chlorine (Ho et al. 2006).
Potassium permanganate is effective for
microcystins, and chlorine dioxide and chlo-
ramine are ineffective
Riverbank filtration and slow sand filtration have
proven very effective in removing microcystins, as
cyanobacterial cells are
retained and dissolved toxin is degraded in
the uppermost substrate layers.

POTASSIUM PERMANGANATE $KMNO_4$





A permanganate dose of 1-1.25mg/L was enough to reduce microcystins concentration below the guideline value of 1ppb. Permanganate oxidation is therefore a feasible option for microcystin removal during preoxidation processes. However, the oxidant dose must be carefully optimized in order to remove extracellular microcystins without causing cell lysis (due to chemical stress) and further release of MCs.

Using nanobubble ozone

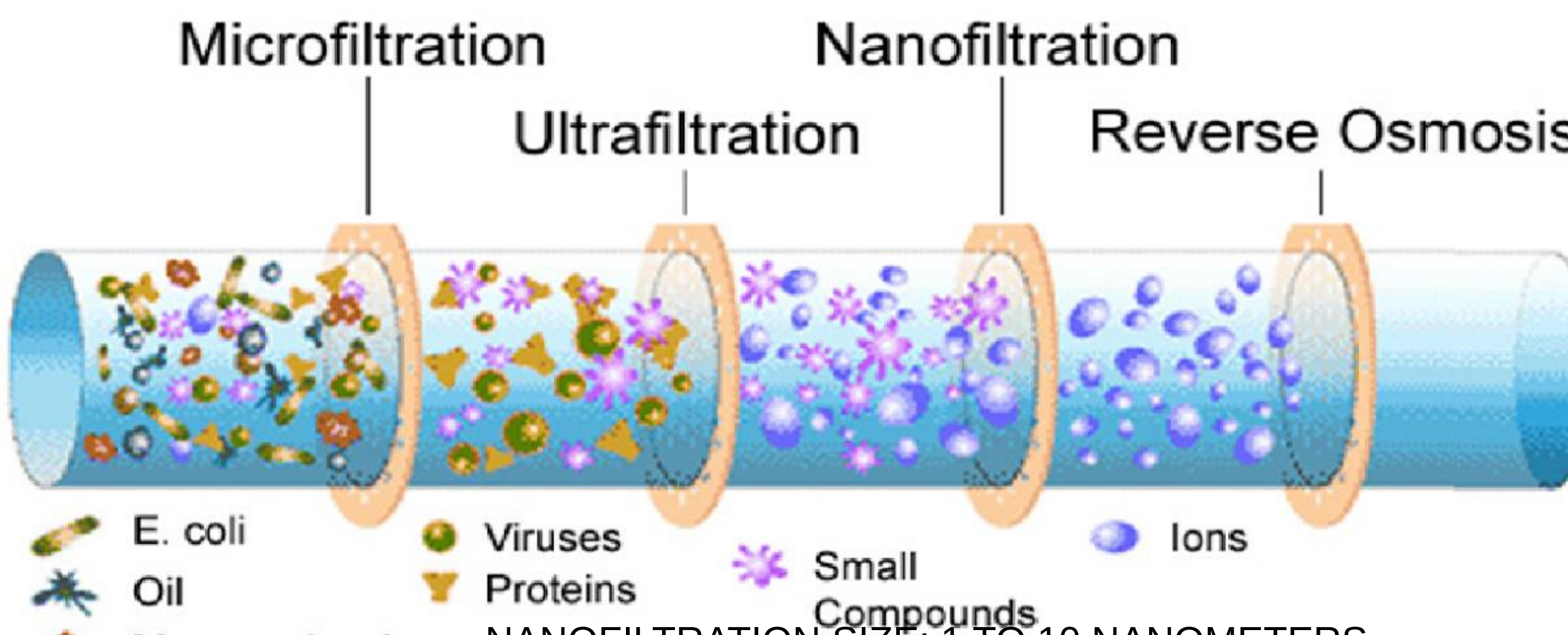
Ozonators **split oxygen molecules into two free oxygen atoms** in one of two ways: **intense ultraviolet (UV) light** or by using what's known as a corona discharge (CD) unit. When these freed oxygen atoms collide with existing oxygen molecules present in the water, they create ozone.

Ozone interferes with the metabolism of **bacterium cells**, most likely through inhibiting and blocking the operation of the enzymatic control system. A sufficient amount of **ozone** breaks through the **cell** membrane, and this leads to the **destruction** of the bacteria.

O_3

OZONATOR

Dissolved microcystins have been shown to be removed by some reverse osmosis and nanofiltration membranes. As removal will depend on membrane pore size distribution and water quality, site specific tests are recommended



NANOFILTRATION SIZE: 1 TO 10 NANOMETERS

- There are 25,400,000 nanometers in one inch

- Microcystin-LR is a hydrophobic molecule with an estimated size of **1.2 −2.6 nm**

The Hazen-Adams CyanoTOX allows utilities to estimate the removal of extracellular cyanotoxins by ozone, permanganate, chlorine, chlorine dioxide, or chloramines.

CALCULATOR INPUT PAGE

STEP 1. Select the cyanotoxin of interest from the dropdown list

Cyanotoxin Type Microcystin-LR (MC-LR) →

STEP 2. Input the following system parameters

pH (between 6-10) 7.7

Temperature (between 10-30°C) 17

STEP 3. Input the initial cyanotoxin concentration

Extracellular Cyanotoxin Initial Concentration (µg/L) 28.4

(If not known, enter an assumed value for the scenario)

STEP 4. Select your target option from the dropdown list

Target. Options: 1) Input target cyanotoxin conc. 1) Input target cyanotoxin conc.

2) No target

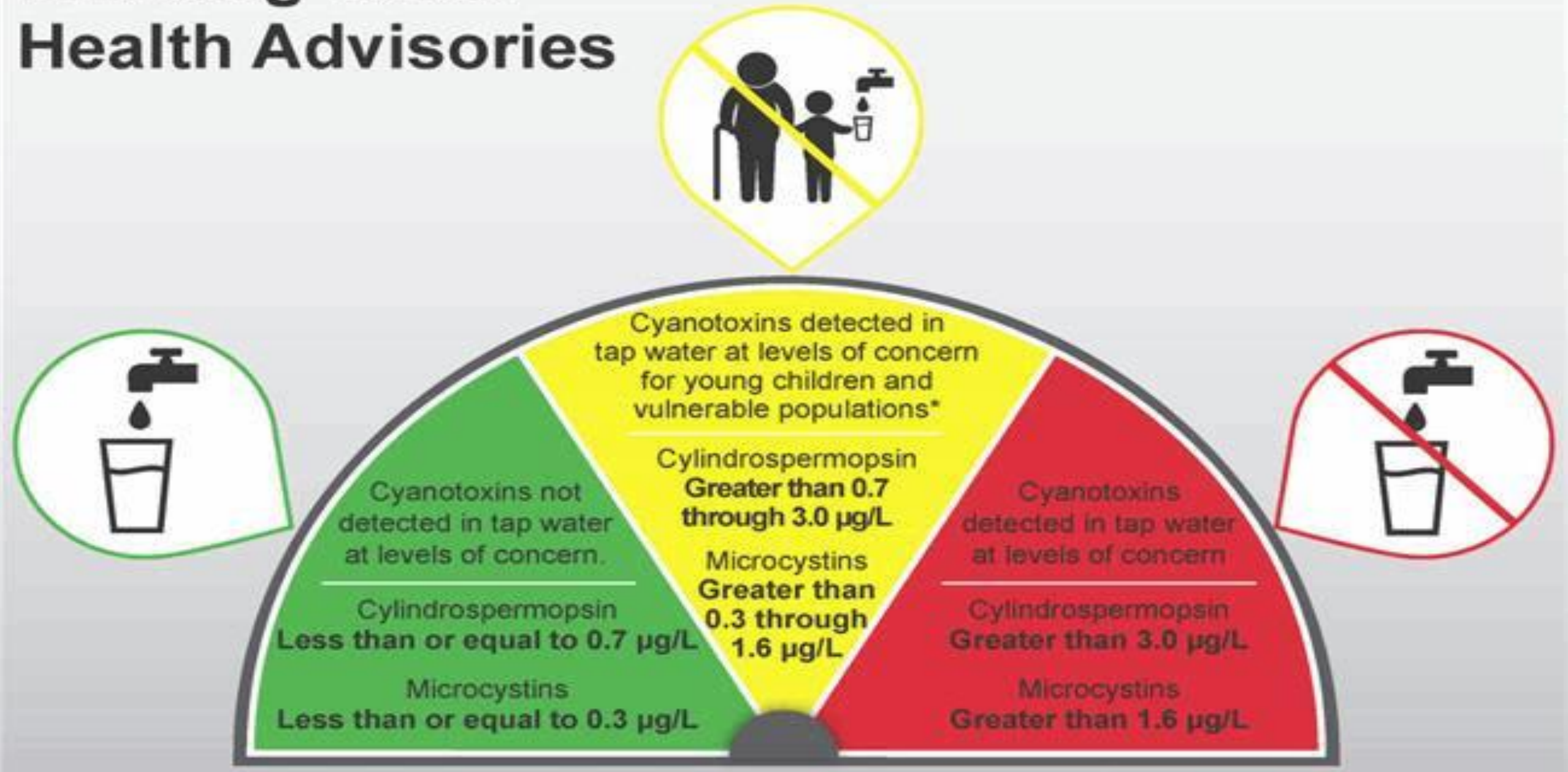
Target cyanotoxin concentration (µg/L) 0.3

STEP 5. Select the oxidant of interest from the dropdown list

Oxidant Type Permanganate

STEP 6. Go to your chosen calculator version: CT based or Dose-decay based (tabs in blue)

Drinking Water Health Advisories



*vulnerable populations = infants, children under the age of six, pregnant women, nursing mothers, those with pre-existing liver conditions, those receiving dialysis treatment, the elderly and sensitive populations.

All laboratories on this list have been certified by Ohio EPA to conduct Total Microcystin testing with ADDA by ELISA Analytical Methodology, Version 2.3, July 2018 (Ohio EPA DES 701.0) and/or cyanobacteria screening using Ohio EPA Division of Environmental Services Method 705.0, "Quantitative Polymerase Chain Reaction (qPCR) for Determination of Cyanobacterial and Cyanotoxin Producing Genes."

Total Microcystin Testing*

Cyanobacteria Screening (qPCR) Analysis*

Alloway - Marion 1776 Marion-Waldo Rd. Marion, OH 43301 (740) 389-5991

✓ ✓

Archbold 300 N Defiance Archbold, OH 43502 (419) 445-2506

✓

Celina Water Dept. Laboratory 714 S. Sugar St. Celina, OH 45822 (419) 586-2270

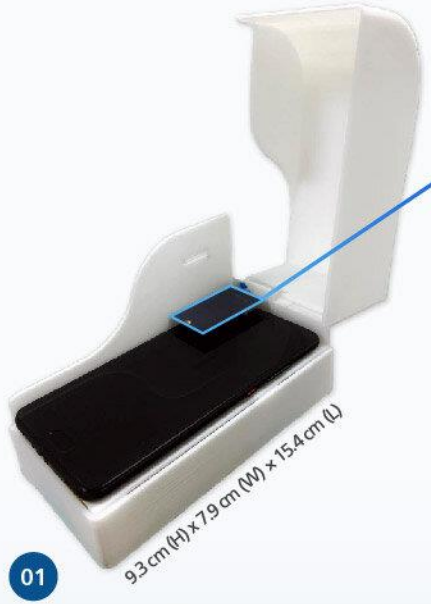
✓

Marysville Water Division 409 N Main St. Marysville, OH 43040 (937) 645-7384
✓
N.E.O.R.S.D. 4747 E 49th St. Cuyahoga Heights, OH 44125 (216) 641-6000
✓
Ohio EPA, Division of Environmental Services 8955 E. Main St. (614) 644-4247
✓ ✓
Oregon 935 N. Curtice Rd. Oregon, OH 43616 (419) 698-7117
✓
The Ohio State University Stone Laboratory 878 Bayview Dr. Put-in-Bay, OH 43456 (419) 285-1845
✓
Willard 540 Central Ave. Willard, OH 44890 (419) 933-4001
✓
Erie County Health Department Laboratory Sandusky, OH (419) 626-5623
✓

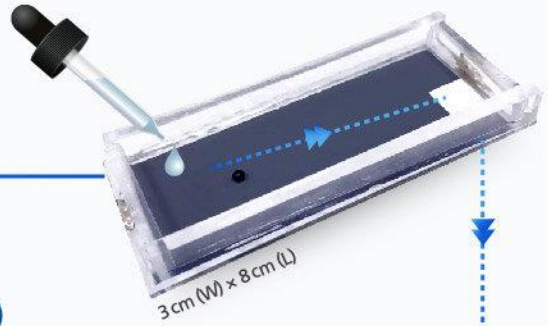
*To determine testing and sample acceptance availability, call laboratories at the listed number. We recommend contacting the laboratory prior to sampling to ensure proper protocol and that samples will be received within holding time.

NUS engineers invent smartphone device that detects harmful algae in 15 minutes

New 'lab-on-a-chip' technology can be used to monitor water quality any time, anywhere

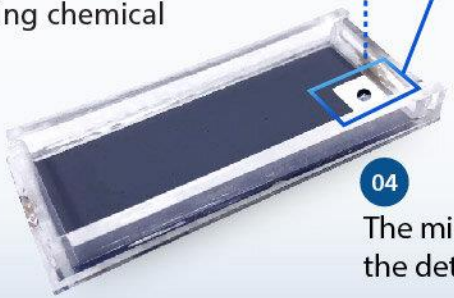


01 3D-printed smartphone platform houses the chip and electronic components

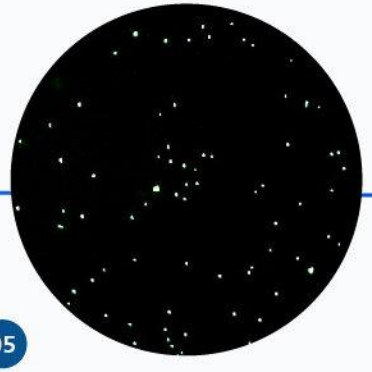


02 Water sample is deposited on the chip which is coated with a layer of photoconductive material

03 The water droplets move along the patterns generated on the screen of the smartphone, and are mixed with a staining chemical



04 The mixture moves into the detection zone



05 Fluorescent images of the stained algae cells are captured by the smartphone camera

06 The images can be sent to an app on the smartphone to count the number of algae cells detected. The images can also be sent wirelessly to another location via the smartphone

Key features

Portable
Less than 600 grams (including weight of smartphone)

Low cost
Less than S$300 (excluding price of smartphone)

That's $211.32 USD

Fast
Generates results within 15 minutes on-site

Accurate
Achieves detection accuracy of 90%; comparable with current analytical methods


THANK YOU
OPERATORS